

A neural field model for planning of saccadic eye movements: dependency of saccadic decision making on target separation and fixation condition

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Selecting one from many objects in the visual field and directing the gaze to it by a saccadic eye movement is a fundamental behavior of primates. The investigation of this behavior by means of the double-target paradigm reveals a dependency of the saccade metrics on target separation and saccade latency. For large target separations the saccade is directed to one of the targets (target selection), for small separations the saccade lands between the targets (target averaging), and for intermediate separations a speed-accuracy tradeoff is observed: saccades are target-averaging for short latencies, but target-selecting for long latencies [1,2]. It has been proposed that this behavior is caused by the successive action of two different neural systems [1].

We demonstrate that the psychophysically observed separation and latency dependent decision making concerning the plan for the impending saccade is a basic property of a neural field model with simple structure. We therefore propose that this behavior is generically generated in the brain structures concerned with saccade planning, and that no complicated neural mechanisms are needed.

A central feature of our model is a pattern of recurrent interaction with short-range excitation and long-range inhibition ("Mexican-hat" interaction). Kopecz and Schöner previously showed for the double-target paradigm that a neural field model captures the dependence of target averaging and selection on target separation due to its Mexican-hat interaction pattern [3,4]. We developed a neurally more realistic extension of the Kopecz-Schöner model with separate layers for excitatory and inhibitory neurons for each neural field. Our model additionally captures the dependency of saccadic decision on latency. The model consists of two fields. In the planning field a saccadic motor plan in form of a single peak of activity (resembling population coded saccadic motor activity in the Superior Colliculus) is generated from the target stimuli. The planning activity is coupled into the fixation field where it competes with fixation activity evoked by a foveal stimulus. When the fixation activity has been suppressed, the elapsed time (saccade latency) and the center of mass of activity (saccade endpoint) are read out. We employed gap, step and overlap fixation conditions which served to produce short and long latencies. The model property which brings about the speed-accuracy behavior is the inhibitory feedback coupling causing the inhibition to lag behind excitation. In the time course of the planning dynamics there is an excess of excitation initially, followed by a balanced state. Therefore, inhibitory competition of stimulus evoked activities leading to target selection takes place at larger target separations for short latencies than for long latencies.

Our model qualitatively reproduces the saccadic endpoint distributions of the psychophysical experiment. Moreover, a prediction is made that could be tested psychophysically: For certain target separations and latencies, both target selection and target averaging can occur. This is indicated by trimodal endpoint distributions.

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